EQUIDAE IN THE NGORORA FORMATION, KENYA, AND THE FIRST APPEARANCE OF THE FAMILY IN EAST AFRICA

Martin PICKFORD[1, 2]

[1] Chaire de Paléoanthropologie et de Préhistoire, Collège de France, 11, place M. Berthelot, 75005, Paris
[2] Laboratoire de Paléontologie,UMR 8569 du CNRS, 8, rue Buffon, 75005, Paris

Pickford, M. 2001. Equidae in the Ngorora Formation, Kenya, and the first appearance of the family in East Africa. [Equidae de la Formación Ngorora, Kenia, y la primera aparición de la familia en África del Este.] *Revista Española de Paleontología*, **16**(2), 339-345. ISSN 0213-6937.

ABSTRACT

Several papers published during the past two decades have denied the existence of equids in the type section of the Ngorora Formation, Tugen Hills, Kenya, despite their discovery there prior to 1975. A long term result of this omission is that the family is generally viewed as having arrived in East Africa as late as Zone MN 11 (between 9.0 and 8.5 Ma), well after its appearance in Europe and North Africa in MN 9 (ca 11 Ma). However, recent surveys in the type area of the Ngorora Formation confirm that the family is present in Member E in sediments deposited about 10.5 - 11 Ma. There was thus no significant offset in the arrival times of equids in Africa, Europe and Asia (Indian Subcontinent included).

Keywords: Late Miocene, East Africa, Equidae, biogeography, biochronology.

RESUMEN

Algunos trabajos publicados durante las dos ultimas décadas han negado la existencia de équidos en la seccion tipo de la Formacion Ngorora, Tugen Hills, Kenia, a pesar de su descubrimiento anterior a 1975. A largo plazo, el resultado de esta omisión es que generalmente se considere que la llegada de la familia a África del Este se produjo tan tardíamente como la edad atribuida a la unidad MN 11 (entre 9 y 8,5 Ma), bastante después de su aparición en Europa y África del Norte en la unidad MN 9 (ca 11 Ma). No obstante, recientes investigaciones en la seccion tipo de la Formacion Ngorora confirman que la familia está presente en el Miembro E, en sedimentos depositados alrededor de 10,5 - 11 Ma. En consecuencia, no hubo diferencias significativas en el tiempo de llegada de los équidos a África, Europa y Asia (incluido le subcontinente Indio).

Palabras clave: Mioceno Superior, África del Este, Equidae, biogeografía, biocronología.

INTRODUCTION

In 1975, Pickford recorded the presence of the equid *Hipparion* at 10 localities within the Ngorora Formation, Tugen Hills, Kenya, including one record in the type area at locality 2/95 (Figs 1, 2). Of the equid fossils collected by Pickford and mentioned in his thesis, only those from Ngerngerwa were described by Hooijer (1975) and this has undoubtedly reinforced the impression that equids don't occur elsewhere in the formation. It should be noted that at the time of Pickford's survey the Ngerngerwa, Poi and Kapkiamu outcrops (Fig. 1) were correlated to Members D and E of the Ngorora Formation, but this is now known to be incorrect and most of them belong to Member E or younger deposits.

Subsequent to Pickford's surveys, Hill and colleagues (Hill *et al.*, 1985, 1986; Tauxe *et al.*, 1985; Deino *et al.*, 1990) continued research on the Ngorora Formation, concentrating in particular on radioisotopic dating (Fig. 3) and palaeomagnetic stratigraphy (Fig. 4). At the time of their studies Hill *et al.* (1985) believed that the earliest record of *Hipparion* in the Siwaliks of Pakistan was about 9.9 Ma (Barry *et al.*, 1982) or 9.5 Ma (Barry and Flynn, 1990) and perhaps due to this preconception, the team was prone to discount Pickford's 1975 results which indicated a substantially earlier arrival of equids in East

https://doi.org/10.7203/sjp.16.2.21608

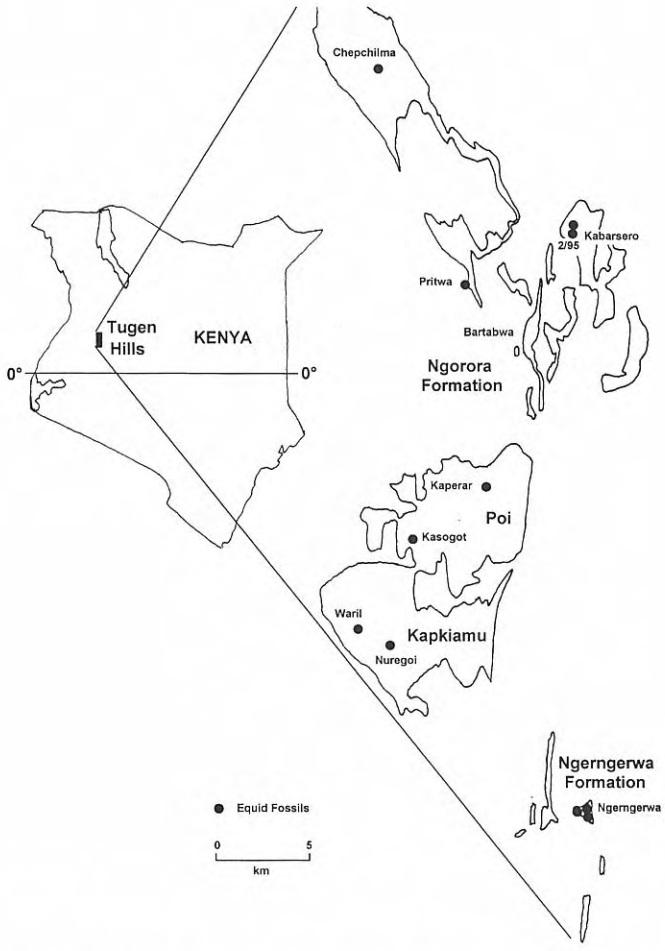

Figure 1. Distribution of equids in the Ngorora and Ngerngerwa Formations, Tugen Hills, Baringo District, Kenya Rift Valley.

Africa some 1.5 to 2 million years before their supposed appearance in Pakistan and Europe (Sen, 1990).

This point of view has been repeated a number of times (e.g. Sen, 1990). The most recent word on the matter is by Eisenmann and Whybrow (1999) citing Hill to the effect that "There are no *Hipparion* fossils in the type section of the Ngorora Formation, only in younger sites; their age is between 9.0 and 8.5 Ma, certainly younger than 10 Ma (Hill *et al.*, 1986) and thus probably belong to MN 11 Zone".

Aguirre and Alberdi (1974) reported the presence of equids in the Northern Kenya Rift Valley at Nakali and on the basis of faunal correlation deduced that the family arrived in East Africa between 10 and 11 Ma. They concluded that "It cannot be shown that the migration of *Hipparion* in Europe preceded that into Africa". Whilst the conclusion is supported by the present paper, the evidencial basis for it is not, because the Nakali levels from which Aguirre and Alberdi obtained their fossils is now known to date from about 9.5 Ma (Pickford, 1986).

During the 1999 field season of the Kenya Palaeontology Expedition, the author carried out a survey of some of the outcrops of Member E in the type area of the Ngorora Formation (Fig. 2). The aim of this survey

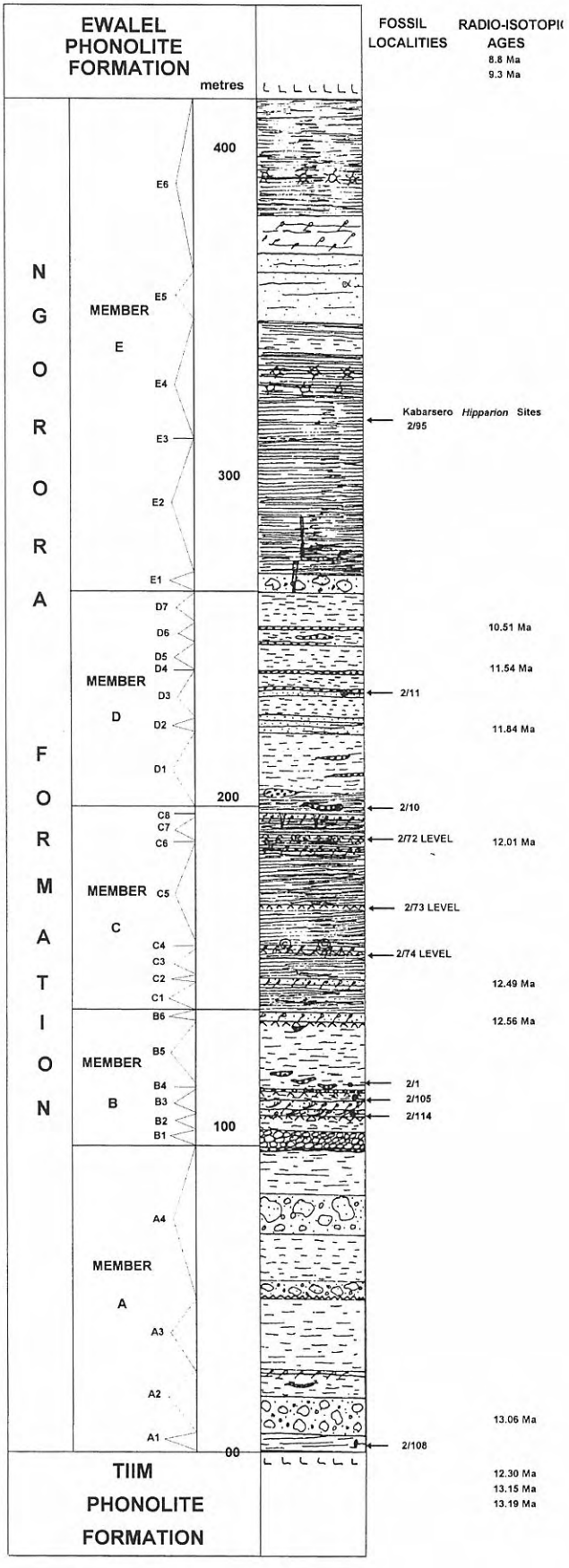

Figure 2. Type section of the Ngorora Formation at Kabarsero, showing fossiliferous levels and the earliest *Hipparion* in the succession.

was twofold - 1) to verify that locality 2/95 (00°54'07"N : 35°50'10"E) which yielded the original sample of *Hipparion* tooth fragments consisted of sediments belonging to Member E of the formation and not to inliers of some younger formation, and 2) to search for additional equid fossils.

RESULTS

It is confirmed that the strata at locality 2/95 (Figs 1, 2) are in continuous outcrop with the base of Member E in the type section at Kabarsero, the fossiliferous level being between 20 and 30 metres above the base of the member, Bed E1 which is a 6 m thick, lahar-like, debris flow with large blocks in it. The equids occur in fluvial sediments within Bed E4 (Pickford, 1975) (Fig. 2).

During the 1999 KPE survey additional equid fossils, including tooth fragments, were found near locality 2/95 at a new site located at 00°54'26"N : 35°50'11"E, also in fluvial sediments of Member E. There can be no doubt therefore that *Hipparion* occurs in the type section of the Ngorora Formation at Kabarsero, in strata aged about 10.5 - 11 Ma, substantially earlier than commonly reported in the literature. Furthermore, *Hipparion* is known from six localities in other parts of the Ngorora Formation as well as in three localities in the Ngerngerwa badlands which were previously assigned to the formation (Fig. 1).

A radioisotopic age determination of 10.51 Ma was reported for a level immediately below Bed E1 (Fig. 2) by Deino *et al.* (1990) in strata that are of reversed palaeomagnetic signature. Although this age estimate accorded with the GPTS of Mankinen and Dalrymple (1979) used by Deino *et al.* (1990) it does not agree with any of the more recently available amendments to the GPTS (Cande and Kent, 1992, 1995; Baksi, 1993; Berggren *et al.*, 1995) in which the magnetic signature for this time period is of normal polarity (see Fig. 4). The strata from which the radioisotopic sample was collected are probably older than 11 Ma, and the radioisotopic age determination is thus probably erroneous.

In Members B to D of the Ngorora Formation, sedimentation rates have been estimated to range between 5 and 25 cm per 1000 years (Deino *et al.*, 1990). If the more rapid rate of sedimentation is used for extrapolating the age of the Kabarsero *Hipparion* fossils then they could be as old as 10.5-11 Ma. If the slower rate is used, then an age of ca 9.5 Ma could result but this is less likely because it is in contradiction with the currently accepted palaeomagnetic stratigraphy of the member. All Member E sediments tested for palaeomagnetic signature are normally polarised (Hill *et al.*, 1985; Tauxe *et al.*, 1985; Deino *et al.*, 1990) and they have consistently been correlated to the "long normal" chron of the Neogene (Chron C5N.2n) (Pickford, 1998). The age span estimated for this chron varies from author to author, but both Cande and Kent (1995) and Baksi (1993) estimate its upper boundary at close to 10 Ma and its lower boundary at close to 11 Ma (Fig. 4), considerably earlier

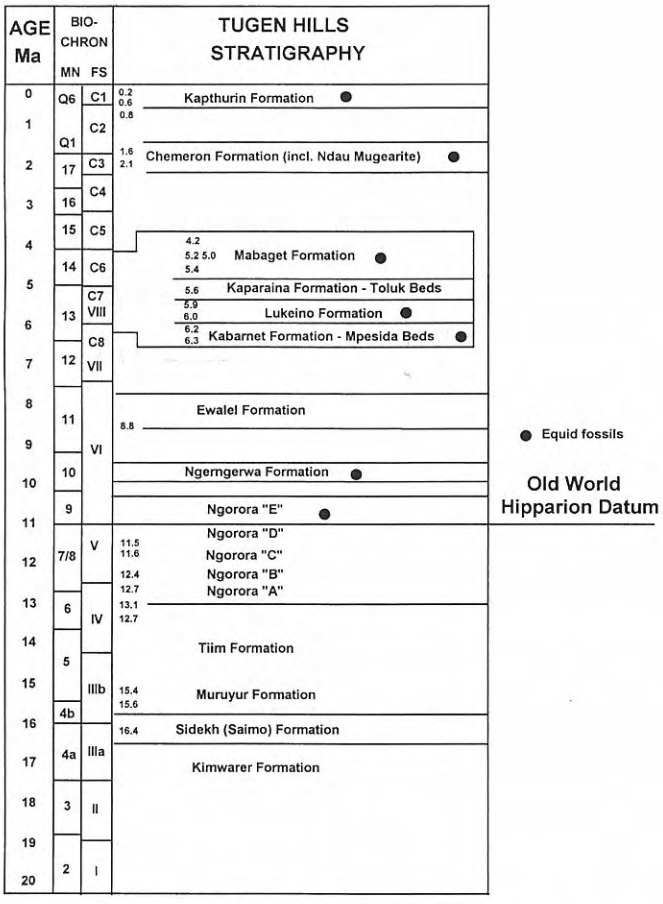

Figure 3. Equid fossils in the Tugen Hills succession, Gregory Rift Valley, Kenya, and correlations of East African Faunal Sets (FS) to European Land Mammal Zones (MN). The Kenyan succession has been dated by radioisotopic methods (small figures to the left of each column). Note that the Ngorora "E" equids lie close to the Old World *Hipparion* datum as worked out for Europe (Daams *et al.*, 1998).

than estimates (9.3 to 9.9 Ma) given by Mankinen and Dalrymple (1979) which formed the basis for initial interpretation of the Ngorora palaeomagnetic stratigraphy (Tauxe *et al.*, 1985; Hill *et al.*, 1985; Deino *et al.*, 1990)(Fig. 4). It was the MD79 calibration that led to the youthful estimate of the arrival of *Hipparion* in Pakistan about 9.9 Ma (Barry *et al.*, 1982), an inference that subsequently appears to have played a significant role in the rejection of the records of *Hipparion* in the Ngorora type section by Hill *et al.* (1985). Recalculation of the age of the Siwaliks palaeomagnetic sequence using the chronology of Baksi (1993) or Cande and Kent (1995) indicates that the earliest record of *Hipparion* occurs in Pakistan about 10.5 to 11 Ma, not markedly different from its earliest records in Europe and Africa. For example, Daams *et al.* (1998) estimated the entry of *Hipparion* into Spain at 11.1 Ma, while Sen (1990) concluded that the *Hipparion* datum in Europe was 11.5 Ma on the basis of the Kastellios Hill palaeomagnetic stratigraphy. The latter site was considered to be far

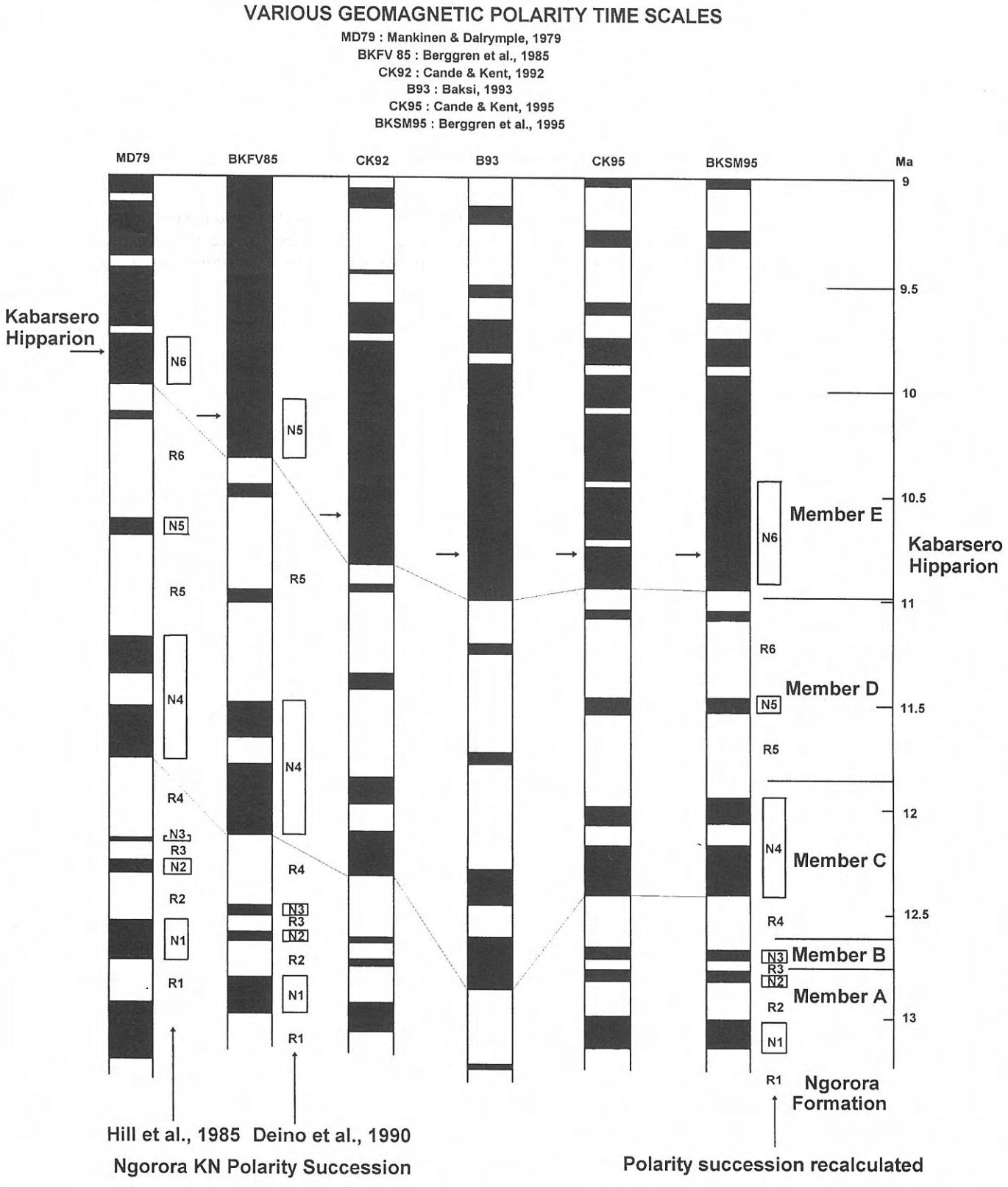

Figure 4. Interpretations of Ngorora palaeomagnetic stratigraphy using various Geomagnetic Polarity Time Scales. The estimated age of Member E of the Ngorora Formation varies according to the GPTS used, but the correlation of the sediments to the "Long Normal" chron remains the same in all interpretations. Correlations using GPTS of CK92, B93, CK95 and BKSM95 yield an age of between 10.5 and 11 Ma for the equids from Kabarsero (type succession of the Ngorora Formation), whereas the GPTS of MD79 and BKFV85 yield substantially younger age estimates for these fossils.

younger by Woodburne *et al.* (1996) who wrote that Kastellios Hill was "irrelevant to the base of the Vallesian and the old age of the *Hippotherium* datum". The latter authors estimated the age of the *Hipparion* datum to be about 10.5 to 11 Ma. Woodburne and Swisher (1995) stressed that 10.8 Ma was "the maximal permissible age" for the *Hipparion* datum.

The old and new evidence from the type section of the Ngorora Formation indicates an appearance of the genus in tropical Africa considerably earlier than 10 Ma (Fig. 3), more in line with other occurrences at Ch'orora, Ethiopia dated between 10.5 and 10.7 Ma (Jaeger *et al.*, 1979; Tiercelin *et al.*, 1979) and North Africa (Jaeger *et al.*, 1976; Sen, 1986, 1990; Woodburne, 1981). The Bou Hanifia, Algeria, occurrence was estimated to be "a little older than 10.5 Ma, but certainly younger than 12 Ma" by Sen (1990) on the basis of palaeomagnetic correlations to the GPTS of Harland *et al.* (1982) in which the base of the "long normal polarity zone" is dated at 10.3 Ma. Accepting Sen's palaeomagnetic correlations, recalculation of the age of the Bou Hanifia equid using more recent GPTS would yield an age of about 11.2 Ma for this occurrence. In contrast, Woodburne *et al.* (1996) estimated the age of Bou Hanifia to be about 9.5 Ma.

FAUNAL CHANGE AT THE MIDDLE MIOCENE - LATE MIOCENE BOUNDARY

Several authors (Pickford, 1975; Hill *et al.*, 1986; Hill, 1999) have noted that there was a distinct faunal shift at the top of the Ngorora Formation. Most of the evidence for originally deducing this change came from strata exposed in the Ngerngerwa badlands previously assigned to the Ngorora Formation, but which occupy a basin that is not in contact with the rest of the formation (Fig. 1). It has been argued (Hill *et al.*, 1985) that these sediments are certainly younger than 10 Ma from which basis Hill (1999) concluded that the distinct change in the nature of East African faunas occurred about 9 Ma as shown by localities in the Ngerngerwa site complex, which he (erroneously) considered provides the "first evidence for the arrival of equids in sub-Saharan Africa".

All known fossil sites in Members A-D of the type area of the Ngorora Formation are older than 11.5 Ma (Hill *et al.*, 1985) (Fig. 3) and none of them have yielded equids, meaning that they most probably predate the arrival of *Hipparion* in the Old World. The presence of equids in Member E of the Ngorora Formation in its type area indicates that an important faunal change occurred in East Africa during deposition of this member. On the basis of faunal, radioisotopic and palaeomagnetic data, Member E correlates with Zone MN 9 of Europe (Fig. 3) and there does not appear to have been a large offset in the arrival times of *Hipparion* in Pakistan (Pickford, 1998), Europe (Agusti *et al.*, 1997; Bernor *et al.*, 1988; Daams *et al.*, 1998; Sen, 1990; Steininger *et al.*, 1998; Woodburne and Bernor, 1992) and East Africa (this paper).

Furthermore the terminal Ngorora faunal shift noted by previous authors started substantially earlier than the 9 Ma estimate made by Hill (1999), and it probably began about 11-10.5 Ma. This was a time of faunal change on a world wide scale (Pickford, 1997a, b, 1998; Pickford and Morales, 1994) and there is no compelling reason to continue holding the view that East Africa was not affected by this change until nearly 1.5 million years after it had occurred in other parts of the Old World. The latter view was only possible when some of the Ngorora evidence was suppressed and when the Geomagnetic Polarity Time Scale used for correlations underestimated the ages of polarity transitions relevant to the analysis.

Furthermore, the confirmation of an early age for the appearance of *Hipparion* in East Africa indicates that the spread of the genus through Eurasia and Africa happened extremely rapidly, imparting greater credence to the concept of an Old World *Hipparion* datum, and weakening arguments that favoured an extensive diachronism in the arrival times of equids in various parts of the Old World.

ACKNOWLEDGEMENTS

Thanks are due to Mr E. Gitonga (Director, Community Museums of Kenya), and Mr K. Cheboi, Miss N. Chemjor, Mrs. E. Kiptalam and Mr D. Chebor for help in the field. The Kenya Palaeontology Expedition was funded by the Collège de France, Chaire de Paléoanthropologie et de Préhistoire (Prof. Y. Coppens). I would also like to thank the Laboratoire de Paléontologie (Prof. Ph. Taquet, Dr B. Senut) for help. Research permission was kindly granted by the Office of the President, Kenya.

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Manuscrito recibido: 19 de enero, 2001
Manuscrito aceptado: 11 de abril, 2001